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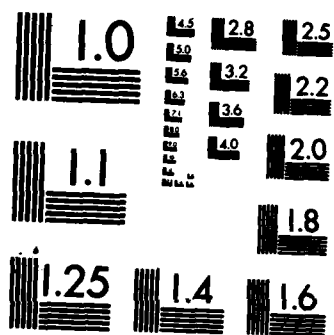
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FINAL REPORT:
RESEARCH ON FACTOR SCREENING
IN COMPUTER SIMULATION

by

Carl A. Mauro
and
Dennis E. Smith

— STATISTICS —

— OPERATIONS RESEARCH —

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Applied Research in Statistics - Mathematics - Operations Research

FINAL REPORT:

RESEARCH ON FACTOR SCREENING
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TECHNICAL REPORT NO. 113-15

March 1984

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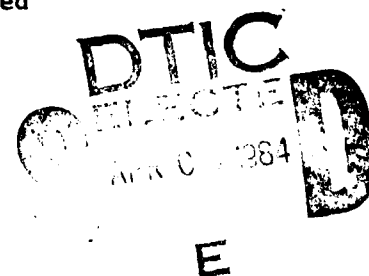


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I. INTRODUCTION

This final technical report prepared under Contract No.

N00014-79-C-0650 summarizes a research investigation conducted by Desmatics, Inc. under sponsorship of the Office of Naval Research.

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The object of ~~the Desmatics~~ ^{this} research program has been to evaluate and compare the performance of factor screening procedures for use in computer simulation experiments.

The following sections of ~~this~~ report briefly discuss ^{the} problem background, summarize ^{the} research goals, and provide ^a reference list of all technical reports, journal publications, and presentations prepared under this contract.

↑

II. PROBLEM BACKGROUND

Computer simulation is often used to study real-world systems that are too complex to be modeled and analyzed entirely by mathematical methods. Unfortunately, simulation models (used to study large, complex systems) tend to be extremely large and complex themselves. Further, corresponding computer programs (codes) used to execute these models usually contain large numbers of factors (i.e., inputs). In addition, these programs can be extremely costly and time-consuming to run. Users of such simulations are often unsure of how to obtain an effective analysis of the system model without having to perform an excessive number of costly and time-consuming simulation runs. Resource considerations dictate that methods of lessening these cost and time burdens be used in order for any fruitful simulation experimentation to take place.

→ Factor screening methods are statistical methods that attempt to identify, efficiently and economically, the set of "most important" factors. Once the most important factors have been identified, further simulation (or real-world) experimentation can focus on these particular factors. This eliminates experimentation with relatively unimportant factors, which can needlessly consume resources. *input*

Many resource-efficient designs have been proposed for conducting screening experiments. Latin squares and fractional factorial designs are among the more traditional designs developed and proposed for use in screening experiments. These designs, however, are generally not applicable in the study of large-scale simulations because they require

more computer runs than are normally reasonable or affordable. In large-scale simulation studies, the number of computer runs is usually severely limited; in fact, the number of factors, K , usually exceeds the number of screening runs, R , that can be made. In statistical design terminology, experiments in which $R \leq K$ are called "super-saturated." This situation has received relatively little attention in the statistical and simulation literature.

III. RESEARCH SUMMARY

The primary goals of the Desmatics research were to (1) review the major types of supersaturated screening designs, (2) select promising procedures for detailed evaluation, and (3) compare the performance of the selected strategies. Three strategies were subsequently selected for detailed study. Two of these were based on random balance sampling and the other on two-stage group screening. The Desmatics research findings are described in a number of technical reports and journal articles. For the simulation user contemplating a screening experiment, these documents offer insight into the various techniques and provide quantitative information on the trade-offs involved in selecting an appropriate screening procedure.

The following pages contain a complete listing of the technical reports prepared under this contract. For each report, the following information is provided: Desmatics Technical Report Number, Report Date, DTIC Number, Title, Author(s), and Abstract. A listing of journal publications and technical presentations is given in Section IV.

Desmatics Report Number: 113-1

Date: March 1980

DTIC Number: AD-A082182

Title: PERFORMANCE EVALUATION OF A SPECIFIC FACTOR SCREENING
TECHNIQUE

Author: Dennis E. Smith

Abstract: In many experimental situations (particularly in computer simulation studies) a large number of potentially important factors exist. Because of time and budget limitations, it is imperative to screen these factors in order to identify a subset which should be subjected to more detailed examination. This paper evaluates the performance of a factor-screening technique which has been proposed for use when it is known that there is at most one active factor (i.e., a factor which has an effect on the response of interest). Performance evaluation reveals that the existence of even a relatively small amount of random error renders essentially useless a procedure which performs well in the deterministic case.

Desmatics Report Number: 113-2

Date: July 1980

DTIC Number: AD-A086449

Title: FACTOR SCREENING IN COMPUTER SIMULATIONS: CONSIDERATIONS
IN PERFORMANCE EVALUATION

Authors: Dennis E. Smith and Carl A. Mauro

Abstract: Although computer simulation is a major area in which factor screening situations are frequently encountered, adequate methodology has not been developed to resolve the factor screening problem. Within the constraint of a limited number of computer runs, a decision must be made about the selection of a screening strategy that will perform efficiently and effectively. This report reviews the major classes of screening designs that have been suggested and recommends two strategies for further research. In addition, a fundamental screening model is defined, and a performance measure for evaluating screening strategies is developed.

Desmatics Report Number: 113-3

Date: October 1980

DTIC Number: AD-A091553

Title: AN EXAMINATION OF THE PERFORMANCE OF TWO-STAGE GROUP
SCREENING FOR USE IN COMPUTER SIMULATION

Authors: Carl A. Mauro and Dennis E. Smith

Abstract: When only a limited number of simulation runs are available, it is usually impossible to thoroughly investigate all of the factors under consideration. Often, though, it is anticipated that only a small subset of the original factors is important. Accordingly, it is desired to screen the factors in order to help identify those that do exert an appreciable effect on the simulation response. Two-stage group screening is one possible strategy that may be used. However, a basic assumption of this strategy is that the directions of possible effects are known, a priori. This report examines, in the case of zero error variance (i.e., when the simulation response is observed without random error), the performance of two-stage group screening when the assumption of known directions is relaxed.

Desmatics Report Number: 113-4

Date: May 1981

DTIC Number: AD-A099703

Title: THE PROBLEM OF EXPERIMENTAL DESIGN IN SIMULATION

Authors: Dennis E. Smith and Carl A. Mauro

Abstract: In many cases, a simulation study may be viewed as an experimental situation in which a number of factors (independent variables) are to be investigated. However, standard experimental design techniques often require more simulation runs than are available to the simulation user. In general, the primary problem of experimental design in simulation can be succinctly summarized as too many factors and too few runs. A discussion of this problem is presented in this report. Three possible two-stage strategies for attacking the problem are considered, and performance measures with which to judge the strategies are described.

Desmatics Report Number: 113-5

Date: August 1981

DTIC Number: AD-A102763

Title: FACTOR SCREENING IN SIMULATION: PERFORMANCE OF A TWO-STAGE
RANDOM BALANCE/PLACKETT-BURMAN PROCEDURE

Authors: Carl A. Mauro and Dennis E. Smith

Abstract: In simulation models involving many factors (input variables), usually relatively few are important. Often it is desired to "screen" out these important factors using a limited number of computer runs. This paper examines the performance of a two-stage screening procedure based on random balance and Plackett-Burman designs.

Desmatics Report Number: 113-6

Date: July 1982

DTIC Number: AD-A117529

Title: FACTOR SCREENING IN SIMULATION: EVALUATION OF A RANDOM
BALANCE/PLACKETT-BURMAN STRATEGY

Authors: Carl A. Mauro and Dennis E. Smith

Abstract: Large, complex simulation models usually must be studied by performing a number of simulation runs. It is often to our advantage to invest a relatively small number of runs in a preliminary experiment aimed at screening out the most important factors. The major experimental effort and expense can then be focused on these key factors. In this report we evaluate the performance of a two-stage screening strategy that is based on a combination of random balance and Plackett-Burman designs.

Desmatics Report Number: 113-7

Date: November 1982

DTIC Number: AD-A121874

Title: FACTOR SCREENING IN SIMULATION: EVALUATION OF TWO STRATEGIES
BASED ON RANDOM BALANCE SAMPLING

Authors: Carl A. Mauro and Dennis E. Smith

Abstract: In the study of large, complex computer simulation models the user is often overwhelmed by the vast number of input variables. Moreover, he or she is usually confused about how to make an effective analysis of the model without performing an excessive number of runs, which tend to be costly and time consuming. Factor screening methods, which attempt to identify the more important variables, can be extremely useful in the study of such models. This paper presents and evaluates two screening strategies based upon random balance sampling. Both strategies are applicable when there are more variables to be screened than there are available screening runs. The results provide guidance in using these strategies in particular screening applications.

Desmatics Report Number: 113-8

Date: May 1983

DTIC Number: AD-A129109

Title: ON THE USE OF STAGEWISE REGRESSION IN RANDOM BALANCE
SCREENING EXPERIMENTS

Author: Carl A. Mauro

Abstract: In this report we investigate the use of stagewise regression as a method of analysis for random balance screening experiments. We also discuss how this method compares with an individual F-test analysis procedure.

Desmatics Report Number: 113-9

Date: August 1983

DTIC Number: AD-A131970

Title: ON THE PERFORMANCE OF TWO-STAGE GROUP SCREENING EXPERIMENTS

Author: Carl A. Mauro

Abstract: Many experimental situations require consideration of a large number of factors. For example, computer simulation studies are frequently characterized by the inclusion of an exceptionally large number of input variables. Because of resource limitations, there is often a need in such situations for an efficient method of factor screening. One possible screening strategy is two-stage group screening. This report attempts to examine the performance characteristics of two-stage group screening experiments as a function of a constant signal-to-noise ratio for all important factors. The effect of group-factor cancellation on performance is also investigated.

Desmatics Report Number: 113-10

Date: September 1983

DTIC Number: AD-A133169

Title: TWO-STAGE GROUP SCREENING SEARCH ROUTINE: PROGRAM DESCRIPTION
AND USER'S GUIDE

Authors: Carl A. Mauro and Kevin C. Burns

Abstract: A computer-aided search program has been developed to help select a satisfactory two-stage group screening strategy. The program is easy to use and provides practical insight into the use and selection of a two-stage group screening strategy. This report describes the program and serves as a user's guide. A listing of the program is included.

Desmatics Report Number: 113-11

Date: September 1983

DTIC Number: AD-A133287

Title: A NOTE ON THE ANALYSIS OF RANDOM BALANCE DESIGNS

Author: Carl A. Mauro

Abstract: In this report the use of separate F-tests as a method of analysis for Random Balance (RB) designs is discussed. The validity of this test procedure is shown by relating the RB model to the exchangeable linear model. For this latter model, the usual F-tests are known to be valid for certain hypotheses.

Desmatics Report Number: 113-12

Date: December 1983

DTIC Number: AD-A136487

Title: A COMPARISON OF RANDOM BALANCE AND TWO-STAGE GROUP SCREENING DESIGNS - PART I

Author: Carl A. Mauro

Abstract: This report is the first of two reports which compare the efficacy and relative merits of a two-stage group screening strategy versus a random balance screening strategy. These techniques for factor screening have potential application in the study of large-scale simulation models.

Desmatics Report Number: 113-13

Date: January 1984

DTIC Number: AD-A137229

Title: DESIGN OF EXPERIMENTS IN SIMULATION

Authors: Dennis E. Smith and Carl A. Mauro

Abstract: In many cases a simulation study may be viewed as an experimental situation in which a number of factors (independent variables) are to be investigated. There are, however, a number of special characteristics that distinguish simulation experiments from statistical experiments in general. In this paper we discuss four topics which we feel are of particular interest and relevance in the simulation context. These are: (1) Identification of the important factors (i.e., input variables); (2) Investigation of the statistical relationship between the output and input variables; (3) Determination of the combination of factor levels for which the response (i.e., output variable) is optimized; and (4) The use of variance reduction techniques.

Desmatics Report Number: 113-14

Date: February 1984

DTIC Number: AD-A137994

Title: A COMPARISON OF RANDOM BALANCE AND TWO-STAGE GROUP SCREENING DESIGNS - PART II

Authors: Carl A. Mauro and Kevin C. Burns

Abstract: In this paper we focus on the problem of supersaturated (fewer runs than factors) screening experiments. We consider two major types of designs which have been proposed in this situation, namely, random balance and two-stage group screening. We discuss the relative merits and demerits of each strategy. In addition, we compare the performance of these strategies by means of a case study in which K=100 factors are screened in N=20,42,62, and 84 runs.

IV. JOURNAL ARTICLES AND TECHNICAL PRESENTATIONS

In addition to the technical reports listed in Section III, significant research findings have been documented in several journal articles. Research accomplishments have also been presented at scientific and technical meetings. A complete listing of journal publications and technical presentations prepared under this contract is given below:

A. JOURNAL PUBLICATIONS

FACTOR SCREENING IN COMPUTER SIMULATION by Dennis E. Smith and Carl A. Mauro, Simulation, Vol. 38, pp. 49-54, Feb. 1982.

THE PERFORMANCE OF TWO-STAGE GROUP SCREENING IN FACTOR SCREENING EXPERIMENTS by Carl A. Mauro and Dennis E. Smith, Technometrics, Vol. 24, pp. 325-330, Nov. 1982.

FACTOR SCREENING IN SIMULATION: EVALUATION OF TWO STRATEGIES BASED ON RANDOM BALANCE SAMPLING by Carl A. Mauro and Dennis E. Smith, Management Science, Vol. 30, pp. 209-221, Feb. 1984.

ON THE PERFORMANCE OF TWO-STAGE GROUP SCREENING EXPERIMENTS by Carl A. Mauro, Technometrics, Vol. 26, to appear August 1984.

DESIGN OF EXPERIMENTS IN SIMULATION by Dennis E. Smith and Carl A. Mauro, American Journal of Mathematical and Management Sciences, to appear as invited paper for special issue on simulation.

EXAMINATION OF A PARSIMONIOUS FACTOR SCREENING TECHNIQUE: SCREENING $K=2^N-1$ -1 FACTORS IN N RUNS by Dennis E. Smith, Communications in Statistics, Series B, Vol. 13, No. 3, 1984.

A COMPARISON OF RANDOM BALANCE AND TWO-STAGE GROUP SCREENING DESIGNS: A CASE STUDY by Carl A. Mauro and Kevin C. Burns, submitted for publication in Communications in Statistics.

B. TECHNICAL PRESENTATIONS

FACTOR SCREENING APPROACHES IN SIMULATION, TIMS/ORSA Joint National Meeting, Washington, DC, May 1980.

PERFORMANCE EVALUATION OF A SPECIFIC FACTOR SCREENING TECHNIQUE, TIMS/ORSA Joint National Meeting, Colorado Springs, November 1980.

THE PROBLEM OF EXPERIMENTAL DESIGN IN SIMULATION, CORS/TIMS/ORSA Joint National Meeting, Toronto, May 1981.

THE PERFORMANCE OF TWO-STAGE GROUP SCREENING IN FACTOR SCREENING EXPERIMENTS, American Statistical Association Annual Meeting, Detroit, August 1981.

FACTOR SCREENING IN SIMULATION: PERFORMANCE OF A TWO-STAGE RANDOM BALANCE/PLACKETT-BURMAN PROCEDURE, ORSA/TIMS Joint National Meeting, Houston, October 1981.

AN EVALUATION OF TWO FACTOR SCREENING STRATEGIES BASED ON RANDOM BALANCE SAMPLING, American Statistical Association Annual Meeting, Toronto, August 1983.

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